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How did Japan Catch up Europe in Regenerated Cellulose Fiber Technology during 1920s-1930s?: A Case Study of Asahi Kenshoku Company, A First Joint-Venture with Germany

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Synopsis: In 1921 Asahi Kenshoku (AKS) had introduced a viscose rayon technology from a German leading company, Vereinigte Glanzstoff A. G. (VGF), forming a first world-scale Japan-foreign joint venture with VGF (20% share holder of the capital) and establishing a plant under guidance of VGF. Afterwards, AKS catched up Europe technology. In this article an attempt was made to clarify the process of catch-up.

1 INTRODUCTION

Since the late 19th century research and development on regenerated cellulose fibers had been actively carried out in Europe, in particular, France, Germany and Britain[1-7]. As results three different processes (nitrate, cuprammonium and viscose processes) had been successively commercialized in Europe during the end of 19th century to early 20th century. Viscose rayon was the last to come into market. The process was based on the technical development (British Patent No. 1020 of 1898) of C. H. Stearn's venture (Viscose Spinning Syndicate), which was financially sponsered by Guido Henckel von Donnersmarck[8]. The venture intended to apply for artificial silk viscose (viscous dope), which was invented by

1 Kamide K., Nishiyama K., *J. Ind. Econ.,Nara Sangyo Univ.*, 15, No. 2, p1～13 (2000).
2 Kamide K., Nishiyama K., *J. Ind. Econ., Nara Sangyo Univ.*,15, No. 3, p1～13 (2000).
3 Kamide K., *J. Ind. Econ.,Nara Sangyo Univ.*,15, No. 4, p81～104 (2000).
4 Kamide K, *J. Ind. Econ., Nara Sangyo Univ.*, 16, No. 2, p81～103 (2001).
5 Kamide K., *J. Ind. Econ., Nara Sangyo Univ.*, 16, No. 3 & 4, p191～219 (2001).
6 Kamide K., *Polymers*, 50, 405 (2001).
7 Kamide K., *History of Textile Industry*, p217～292, Soc. Tex. Machn. Japan, 1993.
8 Kamide K., op. cit., p248～252, 258～260.

the world-known cellulose research chemist C. F. Cross and his assistants, E. J. Bevan and C. Beatle in 1892. Commercialization of the process had been realized in Germany (1903), France (1904) and UK (1905). In 1911 Vereinigte Glanzstoff Fabriken A. G. (VGF) purchased all the right of Germany patents together with the factory of Donnermarck's company, converting their business from cuprammonium process to viscose process[9]. On the other hand, in Japan many fringe ventures appeared, but all failed in commercialization[10,11]. Among them, two ventures, Teijin and Asahi, which were founded on the basis of achievements of laboratory-scale development research at the technical colleges and built the bench-scale plants for commercial production. They soon run into unforeseen difficulties originated from inferior fiber quality and high production cost, which leaded to judgment that the commercialization of viscose process will be impossible by domestic infant technology alone[12]. Both tried to purchase the advanced technology from Europe or USA.

Teijin gave up before long an intension of systematic technology transfer because of high contract fee and as results, they had to import machines and to employ foreign engineers (this was often called "domestic" or "independent" technology[13].). Asahi (strictly speaking, J. Noguchi) had made a contract of technology introduction with VGF[14]. AKS is the first company, which introduced a whole system of viscose rayon technology from Europe into Japan[15]. Asahi Kenshoku (AKS) caught up soon Europe and afterwards,

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9 Kamide K., op. cit., p283~287.

10 Kami Y., *Recent Artificial Silk*, p284~298, Meibundo, 1927.

11 Kamide K., op. cit., p289, Figure 7.19.

12 Kamide K., op. cit., p296, Figure 7.24.

13 Yamazaki H., *History of Japanese Chemical Fibers Industry*, p13, Society of Chemical Fibers Japan, 1974.

14 J. Noguchi had sound experience of making contracts with European companies: Immediately after the graduation of Tokyo University, J. Noguchi had worked twice for foreign companies including Siemens, with which he maintained friendly relations for his life long, and then, he made an abroad trip for sake of Tokyo Electric Power Co. in order to gather the company credit in USA. He had purchased for himself numerous foreign patents besides viscose rayon: Frank-Caro method on calcium cyanamide (1908, Italy), Kazare? Method on ammonia synthesis (1921, Italy), Lilienrot process on ammonium phosphate (1928, Sweden), J.P. Bemberg on cuprammonium rayon (1928, Germany), F. Hansgilg on magnesium (1934, Austri). Then, it is very clear that Noguchi was profoundly active to introduce advanced foreign technologies and also was, unusually, knowledgeable to make contract on technology transfer with Europeans. Unlike Noguchi, the founders of TJK had no such expertise.

15 Kamide K., op. cit., p340~368.

succeeded to develop their original technology, which enabled them to export the machines (for example, dialyzer) and new fiber technology (for example, polynosic) abroad. Numerous senior stuffs at AKS migrated to other Japanese "new-comers" of rayons[16]. This is a typical example of technology transfer through individuals. Research and development activity of 'Asahi men' before, during work at and after their employments at AKS were surveyed in details[17,18].

In this article an attempt will be made to disclose how AKS learnt European regenerated cellulose fiber technology during 1920s-1930s. For this purpose, the following items will be surveyed: (1) Elucidation of the level of technology of Japan when AKS tried to purchase European viscose technology from analysis on the list of foreign inventors applied Japanese patents. (2) The details of the contracts between J. Noguchi and VGF and patent numbers of VGF patents transferred to AKS. (3) Processes of learning, imitation, and improvement (mastering) of German technology and development of AKS owns (creativity). (4) Quality of fibers, expressed by the fineness of individual fiber constituting a yarn. (5) Evaluation of research and development capability of AKS from comparision of the number of Japanese patents applied by AKS with those by its competitors. (6) New viscose technology and fibers diversed worldwide from AKS.

2 TECHNOLOGICAL LEVEL OF JAPAN WHEN AKS TRIED TO INTRODUCE NEW TECHNOLOGY

Table 1 lists the number of Japanese patents, registered by foreigners and foreign companies. Among the foreigners, to whom Japanese patents were awarded, there were no known-engineers. In addition, all these patents were applied not by the company, but by the individuals and were concerned not with viscose process, but with cuprammonium process. It was not until 1920-1925 that two world-renowned cellulose research chemists, W. P. Draeper (Assignee, Teikoku Jinzokenshi (Teijin or TJK)) (1921-1922) and E. Bronnert (Assignee,AKS) (1924-1925) obtained 6 patents each.Their assignees were two Japanese firms which had experienced the small-scale commercial production of viscose rayon, as mentioned before. It is interesting to note that although Teijin insisted that they developed successfully 'independent technology' or technology by themselves, they also tried to introduce foreign technology. In the book published in 1927, Kami (Code no. 2[16])

16 Kamide K., *J. Ind. Econ., Nara Sangyo Univ.*, 17, p73-100 (2002).

17 Kamide K., *J. Ind. Econ., Nara Sangyo Univ.*, 17, p113-136 (2002).

18 Kamide K., *J. Ind. Econ., Nara Sangyo Univ.*, 17, p301 (2002).

Table 1 Number of Japanese Patents applied by foreigners or gners or foreign companies on regenerated cellulose fibers

Year of file	Number	Remark account/breakdown list	% of leading scientist or company
1910	0		—
1911	0		—
1912	0		—
1913	2		—
1914	1		—
1915	0		—
1916	0		—
1917	0		—
1918	0		—
1919	0	Asahi Kenshoku	—
1920	0	(established)	—
1921	3	①	33
1922	8	5①*a	63
1923	1		—
1924	2	2②*b	100
1925	6	4②*c	67
1926	6	2③*d	33
1927	2	③	50
1928	5	③④2⑤*e	80
1929	8		0
1930	12	⑤⑥⑦3⑧*f	50
1931	4	③④2⑦*g	100
1932	18	6③3④2⑤2⑦*h	72
1933	5	2③④	60
1934	0		—
1935	6	2③2④⑤*i	100
1936	0		—
1937	1	④	100
1938	8	6④⑧*j	88
1939	7	4④⑧*k	63
1940	4	④	25

①W. P. Dreaper (UK), ②Emil Bronnert (France), ③J. P. Bemberg A. G. (Germany), ④I. G. Farben A. G. (Germanny), ⑤L. Lilienfeld (Austria), ⑥Glanzstoff-Courtaulds (Germany-UK), ⑦Siemens (Germany), ⑧Oscar Kohorn (Germany)
*a 5① : ①①①①①, *b 2② : ②②, *c 4② : ②②②②, *d 2③ : ③③③
*e 2⑤ : ⑤⑤, *f 3⑧ : ⑧⑧⑧, *g 2⑦ : ⑦⑦,
*h 6③ : ③③③③③, 3④ : ④④④, 2⑤ : ⑤⑤⑤⑤⑤, *i 2④ : ④④
*j 6④ : ④④④④④④, *k 4④ : ④④④④

wrote 'Recently TJK joined with William P. Draeper, an Englishman famous in artificial silk industry, buying all his patent rights in Asia. Then, TJK is expected in future to improve its business by Draeper's guidance'[20]. Therefore, the purchase of Draeper's patents by TJK seems well-known knowledge in Japan in 1920s. However, when S.

19 Kamide K., op. cit., p299, Figure 7.26.

20 Kami K., op. cit., p286.

Kumura (a founder of TJK) met Draeper, who had invented 8 patents, in 1921 in London with TJK's agent , Sei-ichi Takahata (Head of London Branch, Suzuki Shoten those days, of which Teijin was a subsidary), Kumura concluded[21] that all of the Draeper's inventions were worthless and humbug, saying that ' we are pleased to know that our research is by far superior. So, we broke off the talk, paying small money. Note that co-inventor of the Draeper's patents was S. Takahata. In 1948, when Kumura published his memoir after 27 years, Kumura forgot what he did in 1921. Unquestionably Draeper had been highly respected in European rayon industry and his opinions had been cited often in many authoritative books[22]. Anyway, Kumura's assessment (in 1948) for Draeper's inventions was very biased and by far apart from his common reputation in Europe. In AKS case Bronnert was a single inventor and assignee was AKS. These patents were applied in 1920-1921, suggesting that the French Patents, bought by Goichiro Uehata (Code no. 6[16]) during his stay in Europe (1920-1921)[23-25], were these Bronnert's patents and the first assignee should be Asahi Jinzokenshi (AJK). Before 1925 any European rayon manufacturer including VGF had not applied Japanese Patent. This is a powerful evidence supporting an idea that Japan was considered by European not to be able to commercialize the most advanced technology such as viscose and cuprammonium processes because of, at least, its very primitive technological level.

Among 109 Japanese Patents, registered by foreign companies or individuals during 1926-1940. J. P. Bemberg A. G. held 18 patents and I. G. Farben A. G. 22 patents, respectively. The former patents are all concerned with cuprammonium process and the latter are mainly on the spinning method of viscose rayon. The above two major companies, taken together, occupied 37%. From 1926 (this is the filing year and the year of application is approximately 1925) onward, European companies started to apply their inventions to Japan. This fact strongly suggests that major European companies recognized that Japan was now up-grading the level of their technology, which can infringe their own rights. 1925 was the year when Japan succeeded to operate the viscose rayon plant, based

21 Kumura S., *Memories*, p52, 53, TJK, 1948.

22 See, for example, A. Hard, *The Story of Rayon*, p17, United Trade Press Ltd., 1931; Joseph Foltzer (translated by T. Woodhouse), *Artificial Silk and its Manufacture*, p87, 96, 106, Pitman & Sons, 1928.

23 Sugimoto T., *Memories of J. Noguchi* (ed. J. N. Memories Ed. Soc.), p487, 1952.

24 Japan Menka (ed.), *Biography of Matazo Kita*, p39, Japan Menka, 1933.

25 Shibamura Yogo, *A Great Entrepreneur, Jun Noguchi*, p123, Yuhikaku, 1981.

26 Kamide K., op. cit., p352, Table 9.1 and 9.2.

Table 2 Japanese Patents on production process of rayon fiber during 1908-1925

Year of file	Pulp	Alkali cellulose	Viscose solution		Cupramm onium solution	Spinning Machine	
			Sulfation	Dissolution		Drawing, winding	Die
1908							
1909							
1910							
1911							
1912							
1913					③		
1914							
1915							
1916							
1917							
1918							
1919							
1920							
1921		②		②		②	①
1922		③			③		①
1923		③					
1924					①		
1925		①	①	①	①		①

Year of file	Spinning Method		After-treatment	Recovery of resource wast-treatment	Hollow fiber	Miscelle-neous	Secondery processing
	Coagulation bath	General	Scoring, drying				
1908							①
1909							
1910							①
1911							
1912							
1913	③					①	
1914	③						
1915							①
1916						3①*a	
1917	③					①	2①*b
1918							
1919							
1920							①
1921					③		
1922		3②*c	②		③		①
1923							
1924	①2⑤*d	①					
1925	5⑤	2①				③	

①Japaneses, Japanese company, ②co-application by Japanese and foreigner,
③Foreigner and foreigner company, ④① of AKS (and Asahi), ⑤② of AKS (and Asahi)
*a 3① : ①①①, *b 2① : ①①, *c 3② : ②②②, *d 2⑤ : ⑤⑤, *e 2⑤ : ⑤⑤⑤⑤⑤
Table was constructed from ref. 26

on German technology. From this year on Japan was admitted to join the club of advanced countries.

Tables 2 and 3 show the number of Japanese Patent filed during 1908-1925 and 1926-

Table 3 Japanese Patents on production process of rayon fiber during 1926-1940

Year of file	Pulp	Alkali cellulose	Viscose solution		Cupramm onium solution	Spinning Machine	
			Sulfation	Dissolution		Drawing, winding	Die
1926						①4③	
1927	④					③	
1928	④	③	①③	①		④4①	①
1929		①		①	③	2③	③2④
1930			①	③		2①3③2④	
1931		①④		①		4①2③④	①③
1932		①		⑤		5①6③	
1933		①		2①	①	12①④	①
1934		2①	①	3①		④	
1935		③4①2③	④	2①			
1936		3①	①	①			④
1937		①				①	
1938	④	4①③					
1939	④	①		①③	③	①③	
1940		2①2③		2①		①④	

Year of file	Spinning Method		Finishing Scouring, drying	Recovery of resource	Hollow fiber	Miscelle-neous	Secondery processing
	Coagulation Bath	General					
1926		①③					
1927	①	③		①	③		
1928	2③	③		①	①		
1929		①	③	③	④	2①③	
1930	③	①4③④		①③④	④		
1931	①	③	④		①		
1932		2③2①	①	①		6③①	
1933		5③2①	3①	①	④		
1934				①	2①	6①	
1935	③	2①2③④		2①		①	
1936						①	
1937							
1938	④	③	2③④		④		
1939	2①	5③①	①	2③	3①	3①③	
1940	2④①	3①③3④			③④	①	

①Japaneses, Japanese company, ②co-application by Japanese and foreigner,
③Foreigner and foreigner company, ④ ①of AKS (and Asahi), ⑤ ②of AKS (and Asahi)
Trable was constractedcted from ref. 26.

1940 for each step and intermediate products of regenerated cellulose fibers (viscose and cuprammonium processes). Inspection of the tables shows that to what sector research and development had been carried out intensively. That is, (1) All patents registered by Japanese during 1908-1920 are exclusively on after-treatment and have not directly concerned with the manufacture of rayons. This indicates the luck of technological knowledge on the manufacture of rayon at that time. (2) Since 1921 an invention of spinneret of cuprammonium process had first been made public. The patents covering whole rayon process had been filed just in 1925. Note that almost inventors and assignees of the

patents, filed between 1921-1925, were not well-known and there was no example of successful commercialization based on the above patents. (3) Since 1926 (i. e., the initial period of commercialization of rayon in Japan) the patents covering whole process and all intermediates such as alkalicellulose, sodium cellulose xanthate and viscose increased in number remarkably: Improvement of spinning machines were popular in 1930-1933. R & D on viscose solution, alkalicellulose and pulp (in relation to alkalicellulose) was active in 1933, about 1935, and about 1938, respectively. That is, the prima period , in which R & D was performed most actively, becomes later as going against the stream of production process.

Above analysis on Tables 2 and 3 is very consistent with the historical fact that the regenerated cellulose fiber industry emerged first by imports of the products and then, the technical innovation proceeded in the direction of going upstream.

3 INTRODUCTION OF GERMAN TECHNOLOGY INTO JAPAN

3. 1 Details of the contract

Table 4 summarizes briefly the technological contract between J. Noguchi and VGF. Note that since the original version written probably in Deutche (or English) is not available, the Japanese translation[27] was utilized to make the table.

Table 5 collects the list of 21 VGF patents on the viscose rayon, which are estimated to have been permitted in the contract (Table 4) to use for the new company (AKS). They are consisted of 5 patents (Deutche Patent (DP) Nr. 187, 947; 197, 965; 239, 821; 239, 822; 236, 589) held originally by Henckel von Donnersmarck's Company, one International Cartel patent (DP Nr. 240, 846), one Courtaulds patent (DP Nr. 267, 479) and VGF own patents. In other words, they are 19 German patents, a British patent and a Swiss patent. According to literature[29-31], AKS purchased twenties latest VGF patents although the patent numbers were not specified there.

3. 2 What the German engineers had taught AKS

VGF sent in 1923-1924 a mission of five German engineers and technicians to AKS

27 Asahi Nobeoka Rayon Plant (ed.), *History of Asahi Viscose Rayon Factories*, p2～4, Asahi Chem. Ind.,1951.

28 Kamide K., op. cit., p351, 353.

29 *AKS Business Report*, 1st Term (2nd half term of 1922), p2, 1922.

30 *AKS Monthly*, April 25th, 1926.

31 *History of Asahi Viscose Rayon Factories*, p6.

Table 4 Technical contract between Noguchi and VGF (1921)

Item	Content
Date of contract	November 25th, 1921
Place of contract	Berlin
Name of contractor	Jun Noguchi, Hiroshima, Japan and Vereinigte Glanzstoff Fabriken A. G. (VGF)
New company (Article 1)	The company with capital of 2×10^6yen will be established before October Ist 1022. It's capacity will be, tentatively, 1000kg-fiber(150d)/day.
Patent right (Article 2)	The company can utilize in Japan and China all patents and registered trade marks,and designs, owned by VGF and various experiences and Improvements of VGF. VGF will not be restricted, in the regions of Europe and USA, in usage of all possible inventions, improvements or industrial protections applied by the new company.
Exclusive right (Article 3)	VGF will not erect any factory of artificial silk production in Japan and China in the valid period of this contract. VGF will not consult with other the contraction of the AS factory.
Advise and Support (Article 4)	VGF will give advice and guidance and present the design plan and project to the new company. For this purpose VGF will give education to the engineers of the company on the factory top secret, the operation know-how of machines and apparatus, and management of the production process.
Order of equipment (Article 5)	On request of the company and under the charge of it VGF will offer the convenience on necessary machines and tools, which can be supplied in Germany, and according to its request, will order them.
Protection of secrecy (Article 6)	Employers and employee of the company should not abuse the knowledge, obtained on the production of as from VGF. The company will be fined 1×10^5 yen, for any (even, simple) violation, to VGF.
Complication (Article 7)	Dispute between the two company will be mediated by mediation court. If judgment by mediation court is unsatisfactory, the secretary of German Supreme Court (Leipzig, Germany) will select a judge.
Market (Article 8)	Market of the products by the new company is Japan and China. The company should not export, directly or indirectly, to Europe. But, when VGF agrees, the company can export through its agents. Only in the case when the company is unsuccessful in Japan and China, the company can export the product to USA.
Reward (Article 9)	The company will pay: (1) 2×105 yen immediately after the conclusion of the contract. (2) 3×10^5 yen until March 1st, 1922 (3) 2.5×10^5 yen when the installation of the equipments for production capacity of 1,000kg-fiber(150 denier)/day is completed. (4) 2.5×10^5 yen when the production further increases after attaining 1,000-fiber/day or when the amounts of the daily production averaged during the past three months exceeds 1,000kg/day. [Total, 1×10^6 yen]
Joint venture (Article 10)	Capital: 2×10^6 yen VGF 4×10^5 yen (20%)
Valid period (Article 11)	15 years

Table 5 Lists of VGF patents on viscose rayon transferred to AKS

Patent No.	Remarks
Deutche Patent	
Nr. 187,975(1905) *a	Miller Patent: translated to VGF
197,965(1906) *a	
240,846(1908) *a	International Cartel Patent*c
239,821(1910) *b	
239,822(1910) *b	
236,589(1910) *b	
260,479(1911) *b	S. Courtaulds+S. S. Naper*d
274,550(1912) *a	
287,955(1912) *a	
282,789(1913) *a	
283,286(1913) *a	
357,668(1913) *a	
369,560(1915) *a	
308,427(1918) *a	E. Bronnert patent
312,393(1918) *b	
367,972(1921) *b	
406,497(1922) *a	
411,600(1922) *a	
418,523(1924) *b	
Brutish Patent	
No. 139,481(1920)	
Swizz Patent	
Nr. 70,124	

*a; spinning method, spinning bath, *b; spinning & drying apparatus,
*c; international Cartel patent; France Patent No. 394, 586 (Assignee, Societe fraçaise), British Patent No. 221, 405 (1907) (Assignee, G. Courtaulds & Co. Ltd), USPno. 970, 589 (Assignee, L. Ph. Wilson)
*d; Oster Patent, Sweiz Paten, France Pont and USP of British Patent (Assignee, S. Courtaulds and S S. Napper).

Able was constructed from ref. 28 with modification.

(Table 6). Members arrived one by one at Otsu, Japan, corresponding to the progress of construction and operation of the plant.. They stayed there for 7-20 months (average 10 months).

Their task was

(1) Construction of the viscose rayon plant with capacity of one tone-fiber per day, including installment of the German-made machines.

(2) Test running of the plant by overcoming the small, but numerous technical difficulties.

(3) Instruction of the operation know-how of the plant to AKS engineers and technicians (i.e., dissemination of the know-how of production of foolproof rayon).

In addition, Dr. Mehner, head of the mission, was said to have given lessons on chemistry

Table 6 VGF mission to AKS

Position	Name	M/F	Arrival	Departure	Remark
Chief (Chemist)	Dr. Mehner	M	1923 Spring	1924 Nov.	Oberbruch, Elberfeld (Near Archen)
Engineer (Spinning)	Oberndolfer	M	1923 Summer ~Autumn	1924 Autumn	St. Pölten Österreichschen VGF
Technician (Twisting) (Operation)	Schmidt	M	1924 April	1924 Autumn	Lobositz, Erste Böhmische GF (Czech)
Technician (Inspection)	Frau Fuehrenbaus	F	1924 April	1924 Autumn	Oberbruch
Chief engineer	Oppenlaender	M	1922 end ~1923 early Sep.	1924 Autumn	Oberbruch

Table 6 was constructed using data in literature[32-36]

Table 7 Assessment of Dr Mehner to AKS Otsu plant in 1924

Process (Total assessment)	Items needed for further improvements
(I) **Spinning solution**	
(The plant can prepare the spinning solution of 1,500 kg/day)	
(a)	Thermosetting of pipes with help of cork, through which all fluids flow
(b)	Installment of cooling mantle at upper part of the mixer
(c)	Ice-producing machine: Supply of sufficient amount of cool water from the well
(d)	Drying up of the pulp room when the pulp with water content of 11~12% is used
(II) **Spinning**	
(The process is not yet complete in the following items)	
(a)	Spun-filaments
(b)	Handling of spool
(c)	Screw
(d)	Occasional cleaning method of spinneret
(e)	Training of laborers and senior supervision
(f)	Stable operation of pumps at spinning bath (order of German-made pump)
(g)	Materials for filtration of spinning bath
(h)	Tentative use of sodium hypochlorite in place of bleaching powder
(i)	Increase in number of spool carriers and prohibition of usage of iron pipe on the spool bar
(III) **Drying zone**	
(a)	Often troubled traffic of the spool carriers due to inaccurate construction of the

32 Kamide K., op. cit., p353, 354.

33 *AKS Business Report*, Third Term (2nd half term of 1923) p2, 3, 1923.

34 *AKS Business Report*, Furth Term (1st half term of 1924), p3, 1924.

35 *History of Asahi Viscose Rayon Factories*, p8, 9.

36 Sugimoto T., Memories, p20, Private edition.

Table 7 (continued)

carriers, whose width was 5~10 mm narrower than the planned size

(IV) **Twisting and rewinding**

(Fairly well progress was made and the completely satisfactory conditions will be realized in near future because the supervision was remarkably improved)

(V) **Scouring**

(Proper and sure operation)

(a) Removal of resin to dissolve troubles (chlorines and hydrochloric acid fume dissolve iron and its solution and such solution yields yellowish spots on the fibers when dropped on them): Introduction of wooden scouring bar in place of iron bar

(b) Residues, on silk yarn , of white lime soap formed by reaction of cement of bleaching and scouring vessel with scouring oil: Usage of US-made high class oil for cloth

(VI) **Drying**

(Good operation)

(a) Handling of wet silk is satisfactory, but continuous keen supervision by senior person is required, otherwise re-occurrence of lots of break-down of fibers in the process will happen again.

(VII) **Finishing**

(Proper and good operation)

(a) Seriously damaged fiber production and fiber quality, caused by frequent change of foremen and short-term shortage of working force (Female laborers can carry out the reliable work only after finishing 6~8 weeks on-the-job training)

(b) Sure control of humidity to 90% (of relative humidity) in the finishing room. Cooling and thermosetting of the room in dry season, where the silk transferred from the drying room is conditioned for whole day

(IX) **Packaging and stocking**

(Good operation)

(X) **Electric power supply**

(Old high-voltage electric line connecting Kyoto and Otsu was newly installed on the iron towers and defect of oil in the transformers of the in-plant substation was removed and at Otsu distribution office an exclusive transformer was established for AKS. These actions allows AKS' s monopolistic electric consumption in this area. In the past, electric stoppage occurred almost once a day, in some cases three ore more times a day.)

(XI) **Supply of resources**

(Supply of Norway-made pulp and UK-made soda is sure.)

(a) Supply of Ryuma (?) is not certain. Then, use of high quality, low price sodium sulfate manufactured by Nihon Chisso is desirable.

(XII) **Miscellaneous**

(a) Extreme difficulty in Japan of manufacture of durable glass tube, which is connected to sppining pump: Use of German-made pipe

(b) Training of supervisors in order to develop an ability to let laborers behave with responsibility and in perfect order, standing on their dignity and with patience.

to Asahi chemistry graduates[37]. He might have observed that there was some significant gap in academic level between Germany and Japan, recognizing urgent needs for further

37 *History of Asahi Viscose Rayon Factories*, p114.

education to young Japanese.

Mehner presented a report on the present status of AKS on November 19th 1924 to AKS[38,39]. The report is summarized in Table 7.

4 LEARNING OF VGF TECHNOLOGY AND EXPANSION OF THE CAPACITY OF THE OTSU PLANT

Table 8 shows a concise history of change in the production capacity of the Otsu Plant during 1924-1928. The plant in term I was constructed by VGF according to the contract. Expansions in term II and term III were performed by AKS own's initiatives.

Table 8 Expansion of production capacity of AKS Otsu factory during 1924-1928

Construction term (start of operation)	Spinning machine		Total capacity		
	number(*a)	pump type*b	winding type	manufacturer	10^4 lb/year
I (1924 spring)	5(130)	Pp*c	Spool	G*f	60(1924)
II (1925 summer)	5(130)	Pp*c	Spool	J*g	120(1925)
III (1927 autumn ~1928 spring)	50(32)	Gp*d	Centr*e	H*h J*i	400(1926 end)

*a; Number of dies per machine *b; Spinning pump installed for each die
*c; Piston pump *d; Gear pump *e; Centrifugal type (gear drive 50%+motor drive 50%),
*f; German-made (guided by German engineers), *g; Duplicated 'made in Japan' plant of term I
*h; Centrifugal machines were made in Germany, *i; Other machines were made in Japan

Table was constructed using ref. 40~43

Term I[40-43] (Stage of learning)

(1) Reform and further expansion of Zeze plant of Asahi Jinzokenshi(AJK) was performed by Ohobayashi Gummi during Nov. 20th,1922~Jan. 25th,1923.

(2) Main machines were designed and ordered by VGF and manufactured in Germany and shipped to Kobe. Electric motors, which should be installed to the machines, were Japan-made.

(3) Auxiliary machines were manufactured in Japan, based on the VGF's plans (with specifications).

(4) All machines were installed by Japanese engineers and afterwards, VGF mission inspected.

38 *History of Asahi Viscose Rayon Factories*, p12~15.
39 Kamide K., op. cit., p360- 362.
40 Kamide K., op. cit., p362, 363 (Table 9. 3).
41 *History of Asahi Viscose Rayon Factories*, p10.
42 Sugimoto T., op. cit., p24, 34, 35.
43 *AKS Business Report*, 7th Term (2nd half term of 1925), p3, 1925.

(5) Y. Kami (Code no. 2[16]) and T. Sugimoto (Code no. 3[16]) supervised all the construction works (1) and designed and ordered auxiliary machines (3), and supervised installation of the machines (4).

In addition, Kami and Sugimoto had made a budget plan of the plant and surveyed possible Japanese market.

The plant employed the plunger pump to flow the spinning solution through die at constant rate and the spool system for wet-spinning and winding[44]. These were the methods established already for large scale production in Europe and in particular the spool method was originated from natural silk industry and therefore very traditional. The spool method required huge space of washing factory and twisting factory and moreover lots of man powers[45].

Term II (Stage of imitation: Construction; July 1925~Nov. 1925: Start of operation; May 1926)

This plant was completely an imitation of term I factory. So, grand design, machine specifications, ..., were the same as those of term I plant[46]. Every thing was domestic[46,47]. Main machines were manufactured chiefly by Kotobuki Seisakusho, Kyoto[47]. It should be noted that Noguchi thus gave Japanese machine and electric manufacturers the opportunities to challenge to produce highly sophisticated machines so that these companies could grade up their technical level[48].

Term III (Stage of mastering: Construction; ~end of 1926: Start of operation; summer of 1927)

This plant was an advanced type and in part was the most advanced process in the world: The spinning solution was supplied at constant flow rate to the die by gear pump, which was installed to each die. This method was much better to regulate precisely. The centrifugal spinning method was also adopted in term III plant. This method was basically due to Topham's invention[49] and developed, for example, by J. Clayton[50]. Fig. 1 illustrates

44 Sugimoto T., op. cit., p23.
45 Sugimoto T., op. cit., p25.
46 Sugimoto T., op. cit., p24.
47 *History of Asahi Viscose Rayon Factories* p10.
48 See, for example, *Memories of J. Noguchi*, p885~896.
49 Topham Ch., Deutche Patent Nr. 125,947 (1900), Deutche Patent Nr. 127,046 (1900), British Patent No. 23,157 (1900), British Patent No. 23,158 (1900).

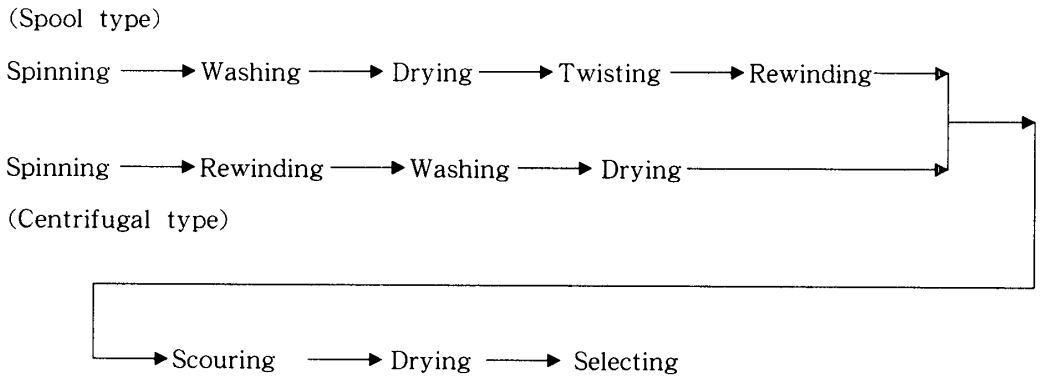

Figure 1 Two processes for production of viscose rayon yarns

the spool and centrifugal processes for viscose rayon yarns. The centrifugal method (mechanical conduction type) had been operated in 1926 on large scale, for example, in two plants of VGF group (Stapel faserfabrik Jordan & Co., Sydowsaue and Glanzfaeden A. G., Petersdorf[51]). This type was the latest machine commercialized on large scale. The rate of rotation of pot was 3,000~4,000[52]. Half of the spinning machines utilized at term III plant in Otsu was this type. Another half was the centrifugal spinning (electric conduction & pot motor[53]), which had been operated on small scale (200 pot motors made by Siemens) at Sydowsaue. The rate of rotation was larger than 6,000 rpm[52] or 5,000~6,000[54]. Note that the spinning velocity is governed by the maximum rate of rotation. But the machine was expensive (machine cost; ¥14~15/spin for mechanical conduction and ¥100/spin for electric conduction[55]) at that time. It was considered that more long-run test operation was necessary for indisputable estimation of the rate of occurrence of troubles, which will govern the production cost heavily. VGF recommended AKS that the centrifugal method (electric conduction type) was premature to adopt at Otsu plant at that time[55]. Nevertheless, AKS ordered 1,100 pot motors to Siemens Schuckertwerke, which had developed pot motors for the centrifuge method. Bernard Moor, Chief of Asia Branch, Siemens and also External Director of AKS (from Nov. 1922 (ASK)~Jan. 1942 (Asahi Bemberg Kenshi); died at Yokohama in 1951?[56]) advised strongly Noguchi to use Siemens

50 Clayton J., British Patent No. 136,769 (1919) and British Patent No. 136,784 (1919).
51 Sugimoto T., op. cit., p28.
52 Sugimoto T., op. cit., p25.
53 See, for example, Clayton J., British Patent No. 139,104 (1919).
54 Lieser Th., *Chemische Textilfasern Filme und Folien* (ed. by Rudolf Pummerer) p417, Ferdinand Enke, 1953.
55 Sugimoto T., op. cit. p28.
56 Sakamoto T., *Memories of J. Noguchi*, (ed. by Editing Association), p670, 1952.

pot motors for the centrifuge method. AKS's daring decision proved later to be very lucky. In term III other machines and apparatus than centrifuge were made in Japan. German pot, which was aluminum pot linered inside with ebonite resin, was replaced with Bakelite pot, which was reinforced with cloth. The latter pot, made by Japanese producer, showed superior performance than the German pots[57].

After 15 years experience of the practical operations, AKS summarized, although not yet authoritative conclusion, advantages and disadvantages of the spool method in comparison of the centrifugal method[58]:

A. Advantage;

(1) Small amount of evolved gas (of course, toxic) in the spinning process.

(2) Little expenditure for repairing, owning to simple mechanism of the machines, consisting of small number of parts.

(3) Easy spinning of fine denier yarns.

(4) Unnecessariness of supplement of the parts.

(5) Easiness of operation even by female laborers of the machines.

(6) Outstanding performance of rewinding process (because the yarns spun by spool method were fully dried at step between washing and rewinding (see, Fig. 1)).

A (4) and A (6) had been highly evaluated in the war-time.

B. Disadvantage;

(1) High labor cost in twisting process (see, Fig. 1).

(2) Tremendous noise caused by the twisting machines.

(3) Low tensile elongation of the yarns due to drying under tension (20.9% by the spool method and 31.9% by the centrifugal method (averaged values during July 1st~December 1st, 1936).)[59]

(4) High occurrence of fuzz, which was detested by weavers.

B (3) and B (4) caused the weaver's low reputation against the fibers.

Table 9 collects labor productivity of the two methods. The table indicates that A (6) is not true merit of the spool method, because labor productivity of rewinding was higher in centrifugal method than in spool method. But B (1) is a demerit of the method. The poor fiber quality was fatal blow to the spool method. Finally, the spool method in AKS was

57 Sugimoto T., op. cit., p39.

58 *History of Asahi Viscose Rayon Plants*, op. cit., p40, 41.

59 Caluculated using the data of ref. 58 (p41).

60 data of ref.58 (p40).

Table 9 Labor productivity of the two methods

Method	Yarn production*a (case*c)	Man powers (man) (day)		Labor productivity (case/manxday)		
		twisting	rewinding	twisting	rewinding	total*b
Spool	75,543	216,236	334,020	0.35	0.23	0.13
Centrifuge	122,656	0	480,705	—	0.26	0.26

*a: Nov. 1937-Oct. 1938
*b: total productivity≡(yarn productivity)/(total man power) $= \left(\frac{1}{0.35}+\frac{1}{0.25}\right)^{-1}=0.13$
*c: 1 case=100*l*b-yarn

Table 10 Business trips of AKS senior stuffs during 1919-1930

Name	Position	No.	Year*a	Route*b	Purpose
J. Noguchi	senior managing director→president	1	1921J-1921Mr	B	contract
		2	1921S-1922F	?	contract with VGF
		3	1928S-1929	D	contract with JPB
		4	1929-1929	C	talk with JPB
G. Uehata	managing director	5	1920-1921	A	contract with Bronnert
		6	1921S-1922F	A	with Noguchi
		7	1922D-1923My	A	shipment of ordered machines
		8	1926Ju-1926end	A	inspection & investigation
		9	1927Mr-1927end	A	inspection & investigation
		10	1928Mr-1928	A	inspection & investigation
		11	1929-1929S	D	talk with JPB (with Noguchi)
T. Sugimoto	section manager	12	1925S-1926A	A	order of centrifugal machines & learning of the method
S. Tachikawa	section manager	13	1926-1927	A	order of vacuum nieder
		14	1928-1928	A	dialyzer
Y. Maekawa	section manager	15	1926-1927	A	with Tachikawa

*a: J; January, F; February, Mr; March, A; April M; May, Ju; July, S; September, D; December
*b: A; Japan ⟷ USA ⟷ Europe, B; Japan ⟷ Indian Ocean ⟷ Europe
C; Japan ⟷ (Russia) ⟷ Europe, C; Japan ⟷ USA

Table was constructed using ref. 63-73

closed on November 26th, 1941 (at Nobeoka Plant)[61]. On the other hand, the centrifugal machines were very short life. In December, 1941, the spinning by the centrifugal machines, which had been overaged at Otsu plant, were suspended[62].

Table 10 lists the records of abroad business trips during 1919~1930 of five AKS senior

61 *History of Asahi Viscose Rayon Factories*, op. cit., p64.
62 *History of Asahi Viscose Rayon Factories*, op. cit., p12.

technical stuffs including senior managing director (J. Noguchi) and managing director (G. Uehata). Data were collected from various sources[63-73]. Here, business trips to Asia were not included in the table, where all trips were numbered. Note that two persons went abroad together four times (Number (2 and 6), (3 and 10), (4 and 11) and (13 and 15)), but counted here separately. For about ten years (during 1919～1929) the above stuffs made business trips 15 times. This indicates that AKS depended significantly on the foreign technology in the above period. The trips were made usually through the following route: Japan～(ship)～USA (west coast)～(train)～USA (east coast)～(ship)～Europe. 6 months were needed for each trip. Exceptions are; trip 1[71], Japan～(ship)～Indian ocean～Europe; trip 3, Japan～(ship)～USA[74]: trip 4, Japan～(train)～Sibiria route[75]～Europe. The main purposes of the trips are the contract on technology transfer (6 times; 1, 2, 3, 4, 5 and 10) and order of machines (5 times; 7, 12, 13, 14 and 15). The purpose of trips varies of course depending on the job positions: Senior managing director; contracts and business talk (trips 1, 2, 3, 4, 5); managing director; contracts (2, 5, 9), order of machines (7), and surveys (7, 8, 10, 11); section managers; order of machines (12, 13, 14, 15). In particular, Uehata made trips 7 times and he was absent in Japan approximately 3.5～4 years in total during 10 years. He was at Otsu in 1924 and 1925, when Otsu plant started and soon expanded its operation.

When Max Fremery[76] (1859 (Koeln)～1932 (Baden-Baden))[77], a founder of VGF visited AKS Otsu plant in 1928, he told G. Ando, the plant manager (Code no. 8[16]) that the water-resistance and high-tenacity viscose yarn will be the most superior and advantageous[78].

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63 *AKS Business Report*, 2nd Term (1st half term of 1923), p3, 1923.
64 *AKS Business Report*, 12th Term (1st half term of 1928), p2, 1928.
65 *AKS Business Report*, 13th Term (2nd half term of 1928), p3, 1929.
66 *History of Asahi Viscose Rayon Factories*, p2, 6, 10, 20, 77, 78.
67 Sugimoto T., op. cit., p15～17, 27～32.
68 Hasegawa Goichiro, *Memoirs I*, p82, 101, 138, Private edition, 1977.
69 *Monthly Report*, AKS, April 25th, 1926.
70 *Deliberation Records of Board of Directors, Asahi Jinzokenshi*, No. 1, 1921.
71 Shibamura Y. op. cit., p122, 123, 125, 223.
72 *Biography of Matazo Kita*, p398, 399.
73 Editing Assoc., *Memories of Jun Noguchi*, p478, 479, 686, 753, 801, 803, 804, 1952.
74 Sakamoto T., *Memories of Jun Noguchi*, p669.
75 Sakamoto, op. cit., p668.
76 Kamide K., op. cit., p234～246.
77 Wicht W. E., *Glanzstoff*, p29, Verlagsbruckerei Schmidt GmbH, 1992.
78 Letter of M. Kita to G. Uehata, cited in *History of Asahi Viscose Rayon Factories*, p20.

Ando reported immediately to M. Kita, the president of AKS, this talk and Kita asked Uehata ,staying in Europe at that time (trip 10 in Table 9), to investigate the high-tenacity yarn thoroughly[78]. VGF commercialized such a yarn later under the trade name of 'Lilienfeld Seide'[79]. Therefore, VGF process was evidently based on Lilienfeld's invention, in which concentrated sulfuric acid or its mixture was utilized as spinng bath (i. e., L. Lilienfeld, British Patent No. 274, 521 (1926) (65~85% sulfuric acid at low temperature), and Deutche Patent Nr. 643, 543 (a mixture of 45~55% sulfuric acid and other mineral acid). Lilienfeld Seide had the tensile strength of 4 gram/denier, which was about twice of ordinary viscose fibers. Courtaulds also adopted the Lilienfeld process for making the high-tenacity cellulose fibers (Durafil^{R}))[80]. After returned to Japan, Uehata gave the technical information on Lilienfeld process to AKS engineers[81,82], saying that 'Now (1927~1928) in Europe a man called Lilienfeld[83] is studying method for production of the high-tenacity artificial silk'. Some young engineers were deeply impressed to hear that. This might be an incentive for creation of 'Polynosic' fiber later.

5 FROM IMITATION TO CREATIVITY : IMPROVEMENT OF OPERATION CONDITIONS AND CREATION OF NEW TECHNOLOGY

AKS absorbed quickly VGF technology, dissolving the problems pointed out by the dispatched German engineers (see, Table 7). For example, very strict temperature control system was introduced into the process[84].

During 1926 and 1929 the improvement of VGF technology was successfully attempted and the original technology, sometimes superior to VGF's was formed. The improvement was first accomplished in the form of alternation of operation conditions. These belong to know-how sector, which, of course, was not made public outside and in consequence the details of all the processes are not clear, but some will be described below :

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79 Lieser Th., op. cit., p404.

80 Moncrieff R. W., *Man-Made Fibres*, p263, 272, 273, Newnes-Butterworths, 1975.

81 Hasegawa G., op. cit., p82.

82 According to Hasegawa, Uehata had not told on the business trips except this opportunity. Now we can understand why Uehata spoke of Lilienfeld.

83 Lilienfeld is well-known as an inventor of the high-tenacity yarn, but before the invention (1926), he had been granted numerous patents covering wide rage of artificial silk since 1906 (during 1906~1923, he applied 25 patents: 20 British Patents, 6 French Patents, 4 Deutche Patents, 3 Oestreich Patents,and 3 US patents). His name was already popular in 1927~1928 although Uehata was ignorant about it.

84 See, for example, Hasegawa G., op. cit., p29, 63, 67.

1. High concentration of sodium hydroxide (normally, lower than 18%)[85], into which pulp was immersed: The concentration was increased to higher than 18% to improve the product (in this case, fibers) quality.

2. High compression ratio of alkalicellulose[86]: Here, the compression (or press) ratio is defined as the weight ratio of alkalicellulose to cellulose (pulp) and the ratio was increased from 3.0~3.2, later to 3.55. Removal of alkali excessively adhered to alkalicellulose was effective for carbondisulfide to react homogeneously with alkalicellulose at late stage. Advantages of usage of alkalicellulose prepared at high press ratio were:

(a) Easy preparation of uniform, fine cellulose xanthate particles without uneven colour.

(b) Increase in solubility of cellulose xanthate particles (a) into sodium hydroxide (to give viscose). Then, the dissolution of xanthate (a) into water became possible.

(c) Reduction of dissolution time.

(e) Easiness of filtration of viscose, which was prepared from xanthate (see (b)).

(e) Reduction of amount of carbondisulfide, needed to produce cellulose xanthate from alkalicellulose.

(f) Removal of hemi-cellulose contaminated in alkalicellulose and level-up of cleanness of the viscose[87].

(g) Decrease of alkalicellulose adhered to crusher (i. e., improvement of the amount of alkali needed to produce the unit weight of fiber).

(h) Super quality fibers (sturdy and tenacity). Note that at that time (~1920s) improvement of fiber tenacity (i. e., tensile strength) was a key priority of R & D of viscose rayon industry.

3. Low alkali viscose[88]: Dissolution of the xanthate [2(b)] into dilute sodium hydroxide at lower temperature was employed to prepare low alkali viscose.

4. High temperature aging of alkalicellulose for shortening of aging time[89] **and the**

85 Hasegawa G., op. cit., p43.

86 Hasegawa G., op. cit., p48, 56~61.

87 High clearness (transparency) of the viscose solutions of AKS was recognized at an exhibition at Mitsukoshi Department Store in 1940, to which major domestic viscose rayon companies had participated (Hasegawa G., op. cit., p60).

88 Hasegawa G., op. cit., p37, 62~66.

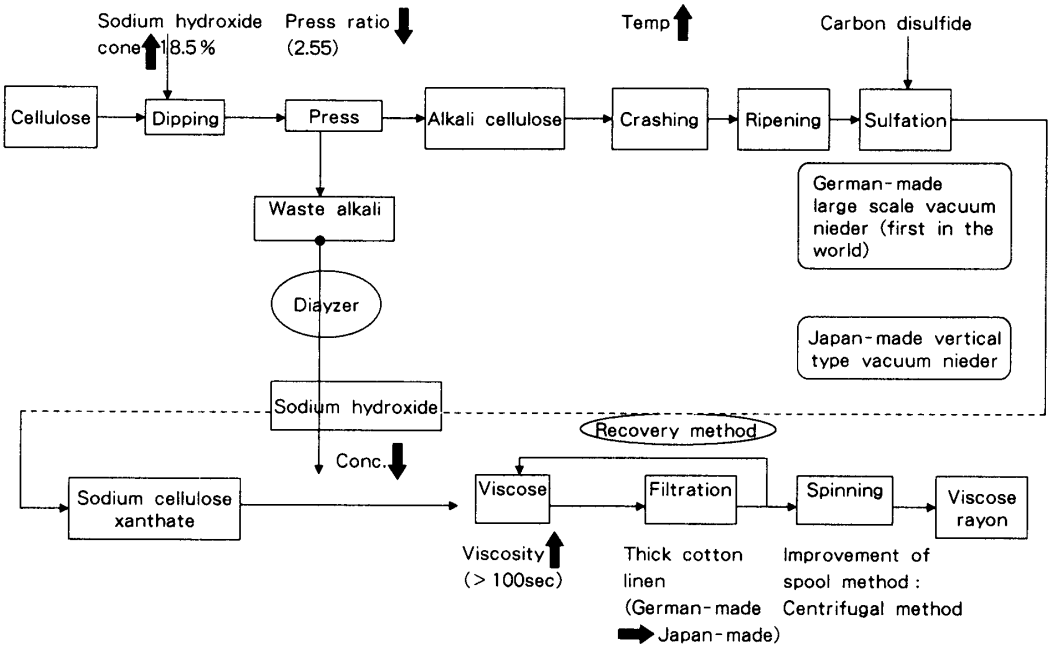

Figure 2 Improvement of operration conditions of German VGF technology by AKS (about 1926~1929)[90] : ➡Improvement

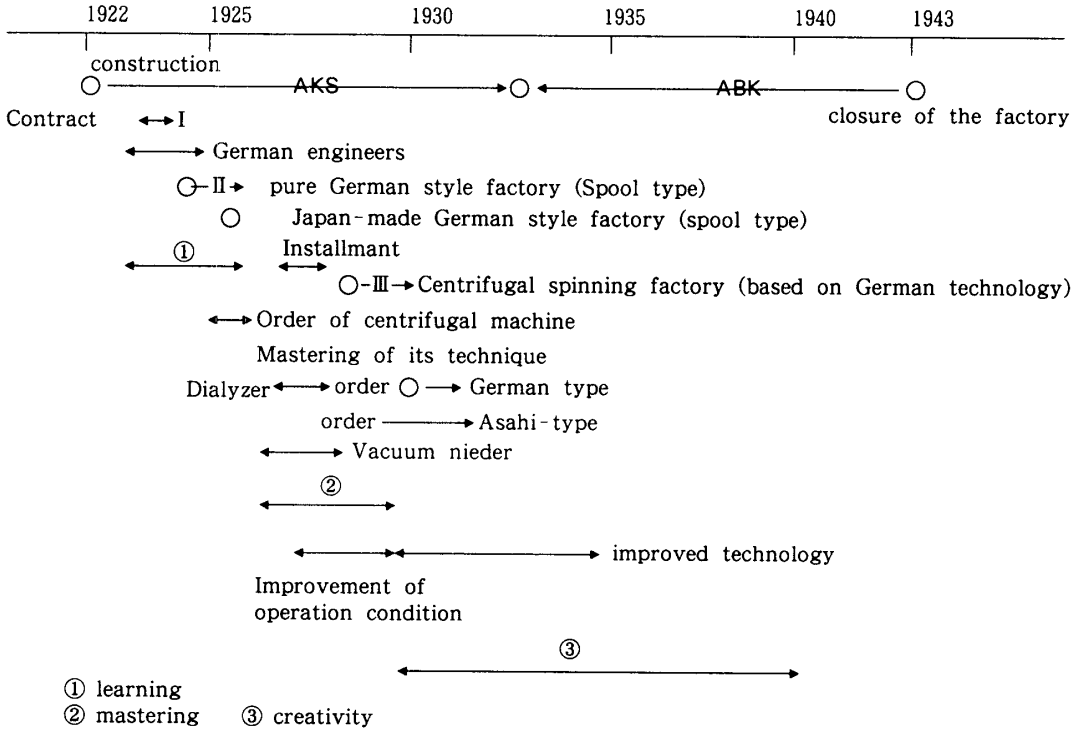

Figure 3 Advance of production apparatus of viscose rayon in AKS and ABK[91]

new method for preparation of viscose without aging of alkalicellulose[89] : Using the heat of alkalicellulose evolved when passing through crusher (see, also 2(g)), aging of alkalicellulose was carried out at 35℃. This resulted in

(a) reduction of space of aging chamber, and

(b) saving of the thermosetting cost.

Fig. 2 illustrates the improvements of operation conditions in the process of viscose rayon manufacture carried out in AKS until 1930.

Fig. 3 shows the advance of machines or apparatus for production of viscose rayon filaments in AKS and its successor Asahi Bemberg Kenshi (ABK) during 1922～1940. AKS imported from Germany and France the following machines for viscose production: Centrifuge machine; 32 sp/machine, 52 machines, Balmer Machininen Fabric[92] (1925～1926); Spinning potmotor, 1100 motors, Siemens[93] (1925～1926); Heibig type dialyzer, 20 machines, total 40 sets (France)[94] (1926～1927); Vacuum-xanthate-kneter, 500*l* volume-the world largest capacity, Werner A. G., specially ordered[95].

6 TYPES OF PRODUCTS

Table 11 collects new brand yarns commercialized by AKS during 1924～1937. When

Table 11 New type fibers commercialized by AKS during 1924～1937

Year (AD)	Month	Commence of production or putting on the market of new brand	Note
1924	May.	150 denier (d) fiber	Spool type (parallel winding)
1925	Jan.	fine denier yarn product 90d (First in Japan)	↓
1926	May.	75d～300d fiber on market	
1927	Feb.	150d multifiber (40d single filaments)	
1935	Oct.	dull yarn and 150d multifiber (50 single filaments)	Centifugal type
1937	Dec.	maximum production capacity	

Table was constructed from ref. 96.

89 Hasegawa G., op. cit., p67～70.
90 Kamide K., op. cit., p375, Figure 9. 8.
91 Kamide K., op. cit., p294, Figure 7. 22.
92 Sugimoto T., op. cit., p28.
93 Sugimoto T., op. cit., p35.
94 Hasegawa G., op. cit., p138.
95 Hasegawa G., op. cit., p37.
96 Kamide K., op. cit., p369, Table 9.5.

Table 12 Denier of single filament of viscose rayon manufactured in some leading companies in middle 1920s

Fiber Denier	Single filament denier			
	ASK (Japan)	Courtauld (UK)	American Viscose (USA)	Sunia (Italy)
75	3.75	5.36	—	—
90	4.5	—	—	—
100	—	4.76	—	—
120	6	—	8.57	6
130	—	—	9.29	—
150	5	7.78	8.33	6.82
200	6.67	7.41	—	—
250	6.25	—	—	—
300	—	—	10.71	7.5
400	—	12.1	—	—
450	—	—	10.71	—

Table was constructed from ref. 98.

AKS started mass production of viscose rayon filaments at 1924 only one brand of 150 denier(24 individual filaments; 150 denier/24 filaments)[97], which was a standard brand in Europe at that time, was put on market. In the next year, AKS succeeded to commercialize fine denier filament (90 denier) as high value added product. This was the first fine denier yarn product in Japan. Within three years since commencement of the plant operation, AKS widened, by improving the original process, the range of the products from 75 denier to 300 denier. In 1927 the multifilament yarn 150 denier/40 filaments (i. e., a yarn of 150 denier consisting of 40 individual filaments: the denier of single filament is 150/40=3.75 denier) was produced. Multifilament yarn was a high quality article. Number of single filaments of a yarn increased up to 50 for 150denier yarn in 1935 and in the same year dull yarn was on market. On December 1937 the yarn production attained maximum.

The fineness of single filament constituting a yarn represents the technical level of the plant. Threads of finer filaments give softer feelings. Table 12 shows comparison of the denier of single filament produced by worldwide manufacturers in advanced countries in about 1926. It is evident that AKS succeeded to produce the finest single filament in the world for given total denier (75~200 denier) yarn.

AKS commenced the sales of viscose yarns on the end of August, 1924. The consolidated profit and loss for three months (between the end of August, 1924 and 3rd Novem-

97 *History of Asahi Viscose Rayon Factories*, op. cit., p120.

98 Kamide K., op. cit., p370, Table 9. 6.

ber, 1924) of AKS were recorded as[99]: Gross sales; ¥611,505: Current profit; ¥124,194: Cumulative deficient until the preceding term; ¥−56,957: Pure surplus; ¥67,236. Then, the loss accumulated for five terms (second half term of 1922～second half term of 1924) was completely cancelled and the gross surplus was accomplished by only three month sales.

The market price of yarns, produced by AKS, was constantly 4～5 yen/100 lb-fiber for large denier yarns (heavy thread) or 10～15 yen/100 lb-fiber for small denier yarns ((light thread) higher than that by Teikoku Jinzokenshi (TJK), the largest competitor[76]. TJK recognized the superior position of AKS products, expressing its comment in the book[100], that "the (AKS) yarn is much white as compared with those of our company (TJK) and the market price of AKS yarns is higher than ours." In contrast to this, Kumura insisted that market price of yarn produced in Hiroshima Plant (of TJK) was strangely higher than that of AKS[101].

AKS fibers had good feeling and were much superior to TJK fibers, which had been commercialized a little earlier than AKS. Therefore, the market price at transaction places of viscose rayon yarns of AKS was listed daily as standard in news papers[44]. However, this superiority of AKS over TJK did not continued for long and reversed within several years[78]. For example, in 1928 the price of TJK was higher by 3～5 yen/100 lb-fiber for large denier yarns or 10～15 yen/100lb-fiber for small denier yarns than AKS[78]. This turnover was said not due to the fiber quality, but to the popularity in the market[102].

7 RESEARCH AND DEVELOPMENT IN AKS

7.1 Patents Registered by Japanese Major Manufacturers As an Index of Capability of R & D

Table 13 summarizes the number of Japanese Patent Publications applied on regenerated cellulose fibers by major Japanese producers in 1916～1940. The patents are,undoubtedly, of potential industrial significance and the number is expected to serve well as an index of capability of R & D of the companies. From the table it is clear that the number of the patents applied by AKS and its successor ABK occupied an overwhelming majority share: Among the total number (89), Asahi held 44 (i. e., (44/89)×100=49%), which is much

99 *AKS Business Report*, 2nd half term of 1924, p7～8.

100 Fukushima K., *History of Teijin* (*Teijin No Ayumi*), Vol. 2, p38, TJK, 1968.

101 Kumura S., op. cit., p63.

102 Hasegawa G. op. cit., p79.

Table 13 Number of Japanese patents on viscose rayon and cuprammonium rayon, whose assignee were Japanese firms, field in 1911-1940

Company	Number of Japanese Patents		
	1911~1929	1930~1940	Total
(1) Asahi Kenshoku ⟶ Asahi Bemberg Kenshi	22	22	44
(2) Kurashiki Jinzoukenshi ⟶ Kurashiki Rayon	14	0	14
(3) Showa Rayon ⟶ Toyo Bouseki	10	0	10
(4) Higashi Kogo ⟶ Teikoku Jinzo Kenshi	4	1	5
(5) Toyo Rayon	1	3	4
(6) Kanegafuchi Bouseki	4	0	4
Total	55	26	81

(1) Asahi, (2) Kurarei, (3) Toyobo, (4) Teijin, (5) Toray, (6) Kanebo
Table was constructed from ref. 103.

larger than that anticipated from Asahi's production share (5~8%) of rayon yarns until 1940.

Since 1924, when Asahi started the partial operation of Otsu Plant, Asahi continued to apply the patents at constant rate. This suggests that Asahi learnt the foreign technology in relatively short period, improving the technical level and further developing the modified process. The competing companies (see, (2), (3), (4) and (6) in the table) decreased the R & D capability over the second ten years. As results, Asahi's share doubled from ((22/55)×100=) 40% for the period of 1911~1929 to ((22/26)×100=)85% for the second period of 1930~1940. Career inventory, research and development activity of AKS's technical stuffs before, during work at and after their employment of AKS were investigated in the previous papers[16-18].

7.2 New technology and new type fiber (Polinosic) emerged from AKS

(1) Dialyzer for recovery of alkali waste

AKS invented new dialyzer and obtained the patents rights worldwide as follows[104]: Japanese Patent No. 89,575 and 92,820; French Patent No. 707,249; Italy Patent No. 297,901; British Patent No.368,783; Swiss Patent No. 165,500; US Patent No. 1,868,955; Argentine Patent No. 44,455.

Above two Japanese patents were amalgamated into single foreign patents.

Economics of waste alkali recovery by dialysis:

103 Kamide K., op. cit., p301, Table 7.19.
104 Kamide K., op. cit., p374.

By employing dialysis for recovery of waste alkali, the amount of caustic soda, which was needed to produce one kg of viscose fibers, was reduced from one or more kg to 0.85 ~0.90 kg[105]. Accordingly, the custic soda unit was improved by about 0.2. Cost of caustic soda in 1937 was about ¥10/100lb-fiber[106]. Recovery of alkali yields a profit of 0.2×10= ¥2/100lb-fiber to reduce the production cost, assuming that the recovered alkali can be sold at the price equivalent to the running cost of dialyzer. Then, recovery of alkali waste contributes to reduction of the total production cost(¥ca. 67/100lb-fiber 107) by about 3%. The profit in 1939 is estimated to be; price−production cost−sales cost=86.5−66.6−6.0 =¥13.9/100lb-fiber[106,108]. Conclusively, the recovery of waste alkali yielded an increase by maximum 21% of the profit in 1937~1939. Note that until 1930 all caustic soda (solid) for viscose rayon had been imported from Britain. Highly pure sodium hydroxide was required in order to produce viscose rayon and only oversea products could fulfill the specification. Then, the economic effect would be greater in 1920s, when the dialyzer was adopted in Japan[109]. It was said in 1937 that caustic soda played an important role in the production cost of viscose rayon and the degree of recovery will affect remarkable influence on the production cost[110]. By invention of the method for recovery of waste alkali the viscose rayon business in AKS became very profitable, and the future of this industry became very prosperous[111].

Comparison of Asahi (AKS) process with Heibig and Cerini processes were made in literature[109]. Asahi type was said to be more economical in USA (~1956)[112]. Development of AKS dialyzer and its legal conflict against TJK was studied on the basis of the patent specifications and the court records in very comprehensive manner by Hirakawa[113].

(2) High-wet-modulus, high tenacity rayon technology

Tachikawa and his coworkers developed new process not based on zinc. Schappel and Bockno[114] evaluated Tachikawa's invention as one of three important evolutions in the

105 Fukushima K., *History of Teijin*, Vol. 3, p18, 21, TJK, 1968.
106 Sugita S., *Artificial Silk Almanac*, 1939, p40.
107 Sugita S., op. cit., p19.
108 *History of Asahi Viscose Rayon Factories*, p101.
109 Kamide K., op. cit., p374.
110 Japan Nitrogen Fertilizers Ltd. (Nihon Chisso), *Business Review*, p499, 1937.
111 *History of Asahi Viscose Rayon Factories*, p23.
112 Oka R., *Chemical Fibers* (ed. R. Oka, E. Munekata, M. Wada), p40~42, Maruzen, 1956.
113 Hirakawa C., *Master Degree Dissertation, Kumamoto University*, 1998.
114 Schappel J. W., Bockno G. C., *Cellulose and Cellulose Derivative*, Part V, p1115~1149,

history of rayon industry. Other two are (1) Mueller acid-salt spinning bath, which enabled viscose commercially practical and profitable (M. Mueller, Deutche Patent Nr. 187,947 (1905), USP No. 836,452 (1906)) and (2) Lilienfeld process, which gave first rayon exhibiting high tenacity polynosic type properties (L. Lilienfeld, British Patent No. 274,521 (1926), USP No. 1,683,199 (1928)).

AKS's and its successer's inventions have the following characteristics[114]

A Toramomen; Tachikawa, 1943

I Viscose:

(1) very low cellulose concentration

(2) very low sodium hydroxide concentration

(3) high carbondisulfide

(4) very underripe

(5) high degree of polymerization cellulose

(6) high viscosity

II Spin bath:

(1) weak sulfuric acid+weak sodiumsulfate

III Stretch:

(1) same as spin bath

(2) stretch ratio; 150%

IV Tenacity of fibers

(1) 3.5 g/d

B Polynosic ; Tachikawa et al., 1950~1960

I Viscose: As for Toramomen above

II Spin bath:

(1) weak sulfuric acid+weak sodium sulfate

(2) low temperature

(3) +very small% of zinc sulfate

III Stretch:

(1) same as spin bath

(2) stretch ratio; 250%

Wiley-Interscience, 1971.

IV Tenacity of fibers: 4.5 g/d

Tachikawa's work was not accomplished by himself alone, but by many collaborators[115,116]. And also, his inventions had confirmedly based on the fundamental scientific works, published elsewhere[117].

8 CONCLUSION

Before AKS commercialized viscose rayon , Japan had been regarded by Europe and USA not to be competitor (Table 1). AKS was the first Japanese company which introduced European technology of rayon (in this case, VGF) through the formal technical contract (Table 4). By the contract about 20 VGF patent rights were transferred to AKS (Table 6). VGF mission of five German engineers (Table 6), dispatched from three plants of VGF group, visited Japan to guide the plant construction, installment of German-made machines, operation of the plant, and the product evaluation. This was a stage of learning. Head of the mission evaluated the level of operation of the plant (term I) at the moment of his departure (Table 7). They guaranteed the plant could produce rayon yarns of two ton per day, which was twice of the contracted capacity. In the next stage, AKS founded the second factory (term II) (Table 8), which was just the same as the first plant, although everything was made in Japan. This was a stage of imitation. Next, AKS opened the third plant (term III) (Table 8) of the most advanced process (gear pump and centrifuge with electric potmotor), which was at pilot plant stage at VGF, on large scale. This was a stage of mastering. The construction of term III was carried out in spite of oppositional advice of VGF. Senior stuffs made constantly the business trips to Europe in order to introduce new technology, to purchase machines and to obtain the latest technical informations (Table 10). G. Uehata went abroad seven times during approximately ten years. Operation conditions of VGF's viscose process were considerably modified to produce the high-tenacity rayon fibers and these improvements leaded later to emergence of 'polynosic' (Fig. 2). Development of machines was made and some of them (for example, dialyzer) were exported (Fig. 3). The AKS products were highly regarded and only after 3 months of starting of sales, accumulative deficient until preceding term was completely cancelled. New brands ranging from fine denier yarns to large denier yarns widened the usage (Table

115 Hasegawa G., op. cit., p126, 180.

116 Hasegawa G., *Memoirs II*, p176-177, Private edition, 1979.

117 See, for example, ref. 17 and 18 (Fig. 6).

11). Within a several years since the commencement of commercialization AKS attained to the technical level, comparable to that of foreign leading companies. (Table 12). R & D capability of AKS proved to be dominant, occupying 49% in number of whole Japanese patents applied by Japanese manufacturers during 1911～1940. (Table 13). AKS's occupancy almost doubled in the second 10 years. AKS developed new technology, such as (1) dialyzer for recovery of alkali waste, and (2) high-wet-modulus tenacity rayon ('polynosic'), exporting the machines and licensing the patents to the advanced countries.